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A STUDY ON THE PALATABILITY OF UREA-CONTAINING FEED MIXTURES FOR DAIRY COWS

by

Howard Fredeen

Department of Animal Science

UNIVERSITY OF ALBERTA

April 1947

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A STUDY ON THE PALATABILITY OF UREA-CONTAINING FEED MIXTURES FOR DAIRY COWS

Howard Fredeen
Department of Animal Science

A THESIS
submitted to the University of Alberta
in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE

Edmonton, Alberta
April, 1947.

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I am particularly indebted to Dr. J. E. Bowstead, Associate Professor of Animal Husbandry, under whose guidance this experimental work was done and who gave much helpful criticism and advice in the preparation of this thesis. Grateful acknowledgement is also extended to Professor J. P. Sackville, Head of the Department of Animal Science, for placing at my disposal the facilities of his department. Many thanks are due Mr. L. S. Brooks, Dairy Herdsman, University Livestock Farm, who devoted much time to the care and feeding of the experimental animals.

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A STUDY ON THE PALATABILITY OF UREA-CONTAINING FEED MIXTURES FOR DAIRY COWS

INTRODUCTION

Urea is a white, crystalline, water-soluble solid composed of carbon, hydrogen and oxygen. It has a characteristic bitter taste and has long been known as the chief excretory product of protein metabolism in the animal body. Its synthesis by Wohler in 1828 is one of the earliest recorded instances of the laboratory preparation of an organic substance.

In recent years several methods have been discovered for the mass industrial production of urea. The newest and the most direct process depends upon the interaction of liquid ammonia and liquid carbon dioxide in an autoclave.

$$2NH_3 + CO_2 \longrightarrow CO(NH_2)_2 + H_2O$$

Synthetic urea has been used extensively as a nitrogen fertilizer and in the manufacture of certain plastics. During the war years it attained particular prominence as a substitute for vegetable and animal proteins in ruminant nutrition. This use, which was first suggested almost 70 years ago, was first authorized in the United States in 1941. In 1946 over 700,000 tons of commercially mixed feed containing urea were fed in the United States.

REVIEW OF LITERATURE

Experiments conducted in 1879 by Weiske, Shrodt and Von Danger demonstrated a possible significance of non-protein nitrogen in ruminant nutrition. On the basis of this and subsequent reports Armsby (1), in 1911, advanced the theory that microorganisms present in the rumen might synthesize protein from non-protein nitrogen.

Many of the data from feeding trials conducted after this date failed to substantiate the theory. Mitchell and Hamilton (22), in a review of the literature available up to 1929, concluded that the evidence presented was conflicting and confusing and did not support any theory of utilization of non-protein nitrogen by ruminants. Even as late as 1937 Krebs, stressing the highly controversial nature of the results obtained in experimentation to that date, was not willing to state that the theory was justified.

However, in 1941 Owen (24) and Benesch (4) in separate reviews of the most recent experimentation concluded that the problem had reached a practical stage and that urea demonstrated protein-sparing action in maintenance, growth and milk production of ruminants.

The experimental data that have brought about this acceptance of Armsby's theory are deserving of a brief review.

From the University of Reading Bartlett and Cotton (2) in 1938 published the results of an experiment of four months'

duration in which 21 dairy heifers were fed three experimental rations - basal low-protein, basal plus urea, and basal plus normal protein (ground nut protein).

The urea mixture was somewhat unpalatable but statistical analysis of the data indicated that the urea nitrogen was used in metabolism. Analysis of blood samples from cows of the urea-fed and protein-fed groups did not reveal any significant differences in their urea and non-protein nitrogen content.

The following year Hart et al.(10) at Wisconsin presented evidence that urea and ammonium bicarbonate were utilized by growing calves. The most efficient utilization apparently took place when a soluble sugar, such as corn molasses, was fed in the ration. Their data also indicated that too high a level of urea in the ration - in this case 2.8# of urea per 100 pounds of ration - caused diuresis, kidney damage, and an increased urea level in the blood.

To establish the nature of this utilization of non-protein nitrogen, Wegner et al. (30), also of Wisconsin, carried out experiments to demonstrate the "in Vitro" conversion of inorganic nitrogen to protein by microorganisms from the cow's rumen. Rumen liquid, secured from the rumen by means of a paunch fistula, was used to inoculate artificial media containing urea. They were able to demonstrate that, on incubation, the inorganic nitrogen disappeared, total nitrogen remained unchanged, and the protein nitrogen increased.

Following this experiment they conducted an "in vivo" study with a rumen-fistula heifer and concluded that this pro-

vided definite proof of the conversion of urea to protein (31).

Their techniques were not without fault and other workers, attempting to duplicate the "in vivo" experiment, concluded that the heterogeneous nature of the rumen contents made a reliable interpretation of results impossible.

The results of their "in vitro" experiment were confirmed by Pearson and Smith (26) of the Hanna Dairy Research Institute. Their work, done with incubated rumen ingesta, proved conclusively that conversion of non-protein nitrogen to protein did occur and was microbiological in nature. Continuation of this research proved that the protein synthesized was actually built into bacterial cells (28).

The most recent work on this phase of the investigations is that of Johnson et al (14), 1944. Their data add additional proof to the theory of bacterial synthesis of protein from dietary non-protein nitrogen in the paunch of the ruminant. They also demonstrate the relative non-importance of the rumen protozoa in this protein synthesis, which is in accord with the conclusions of Becker et al.(3) and Smith.(28).

Concurrent with this phase of the investigations was a continuation of feeding trials with various classes of ruminants designed to demonstrate the comparative value of urea and the normal protein supplements in maintenance, growth, and production.

Many of the data on the feeding value of urea for dairy cattle come from Wisconsin. The work of Hart et al.(10) with dairy heifers has already been mentioned. Rupel et al.(27)

in 1943 published the results of a 3-year experiment in which 18 Holstein cows spent one complete lactation period on each of 3 different grain rations - basal low protein, basal plus 3% urea and basal plus linseed meal. Another group of six cows received the urea mixture plus 10% molasses for three consecutive lactations. From the standpoint of breeding history, calf weights, production, composition and flavor of milk, maintenance of body weight of cows, and composition of the blood, the urea ration proved as suitable as the linseed meal ration.

Hastings (11), in 1944, conducted a feeding experiment with a herd of registered Holsteins whose average production record was 437 lb. of butterfat and 12,933 lb. of milk. Seven cows, chosen as a test group, received a grain ration containing 3% urea while another group of 7 cows was fed the control ration containing linseed meal. Milk production during these seven months did not differ between groups and the percentages of butter fat and protein did not differ significantly. No cases of unpalatability with the test ration could be traced to the use of urea.

Similar results were reported by Owen et al. (25) of the Hanna Dairy Research Institute at the conclusion of an experiment in which urea was fed to 7 lactating cows in an amount equivalent to 25% of the total nitrogen of the ration. Blood analyses indicated that the urea content of blood and milk tended to increase at the start of a urea feeding period and then return to normal as the feeding period progressed.

The most recent report is that of Willet et al.(33) on the use of urea in rations for dairy cows in Hawaii. Twenty-six cows were employed in a "double change-over trial" with feeding periods of 18 weeks. The urea test ration contained 2.5% urea. These workers concluded that the dairy cow is not able to utilize urea nitrogen as effectively as nitrogen from normal protein sources since cows on the urea ration showed a reduced production of fat-corrected milk.

In carefully planned metabolism trials with lambs Harris and Mitchell (7, 8) demonstrated that urea was almost as efficient as casein in maintaining nitrogen equilibrium. They also proved that urea, administered to sheep in amounts commensurate with their requirements for maintenance, was not excreted through the skin (in contradiction of previous reports) and from further trials concluded that the addition of urea to the ration at the rate of 3.16% on the dry basis did not exert any observable toxic effect on the lambs.

They were confronted with a problem of palatability and found that the most satisfactory method for feeding urea was to dissolve it in corn syrup or corn molasses (21).

Four years of feed-lot experimentation with lambs at Cornell (1940 to 1944) (34) failed to indicate that urea was of value when fed as a substitute for linseed meal. However, these workers state, "It was difficult to keep on feed the lambs fed urea nitrogen as a substitute for all the linseed meal nitrogen" and we might expect that this unpalatability could have an adverse effect on rate of growth.

Most recent experimentation has been designed to study the influence of certain dietary constituents on the utilization of urea.

In 1942 Mills et al. (19) demonstrated that the microorganisms responsible for the synthesis of protein from urea nitrogen required a source of readily available energy to effect the most efficient synthesis. In later experiments with a rumen-fistula heifer (20) they found that starch or some other carbohydrate less soluble than molasses was required for the greatest efficiency. In these experiments addition of casein was noted to produce the same effect as the addition of starch.

This supplementary effect of casein was also noted by Johnson et al. (13) in experiments with sheep but not until 1945 was this subject intensively studied. In that year Loosli and Harris of Cornell (16) reported on feeding trials demonstrating a supplementary effect of methionine when added to urea rations fed to lambs. This has initiated a new phase of research on the nutritional requirements of the microorganisms of the paunch and on the probability that such supplementation will increase the value of urea in rations.

There have been many other experiments involving the utilization of urea nitrogen by ruminants. Some have studied the value of urea in maintenance rations (29), some have studied the toxicity of urea (35), while others have investigated the biological value and digestibility of urea. The overall results of these experiments may be summed up in the following words:

The following notes:

Non-protein nitrogen has a definite value in ruminant rations and its value as a protein substitute is influenced by dietary factors which affect the growth of the rumen microfauna.

Urea as the source of non-protein nitrogen may have toxic effects (an increased urea blood level, diuresis and kidney damage) if fed in excess, but amounts up to a level of 1% of the dry material in the ration have not proved harmful. The usual recommendations are that urea may be fed so as to constitute not more than 1% of the dry matter in the ration or 3% of the concentrate mix, or that the protein equivalent of the added urea nitrogen shall not be greater than one-third of the total crude protein nitrogen of the ration.

The unpalatable nature of urea has been borne out by several experiments (2, 6, 15) and it is possible that palatability may be a limiting factor in the use of urea as a protein substitute.

UREA-FEEDING EXPERIMENTS AT THE UNIVERSITY OF ALBERTA

In the fall of 1943 experimentation was initiated at the University of Alberta to determine the value of urea under Alberta feeding conditions. The experiments, which extended through the winters of 1943-44 and 1944-45 were financed in part by a grant from the Consolidated Mining and Smelting Co.

Since many of the data previously reviewed were published after the commencement of these trials they were not available as a guide in planning the experimental approach to be followed.

First Experiment: 1943-1944

Four pair of cows were chosen for this experiment. They were matched for breed, milk flow and stage of lactation but it was not possible to match them evenly for butterfat test. One cow of each pair received the linseed meal grain mixture containing enough of the natural protein supplements to raise the crude protein equivalent to 17.2% and the other cow of each pair was fed a grain mixture in which all of the linseed meal and a small portion of the wheat bran was replaced by 2 1/2% of urea. Enough of the carbonaceous feeds were added to this urea mixture to give it practically the same T.D.N. content as the linseed meal mixture. Table I gives the composition of these two grain mixtures.

Table I

Composition of Urea and Linseed Meal Grain Mixtures

	Urea	Linseed Meal
Wheat bran	390	400
Oats	1249	800
Barley	312	200
Urea	49	-
Linseed meal	-	600
	2000	2000
Crude protein equivalent (N x 6.25)	18.0%	17.2%

Roughage requirements of all cows were met by a ration of oat-silage and mixed timothy-alfalfa hay. All cows were fed according to Morrison's feeding standards and using weekly data on production and body weights.

Two pair of these cows were fed the experimental ration for 14 consecutive weeks while the other two pair received it for 9 and 7 weeks respectively.

Table II summarizes the results obtained in this feeding trial.

Table II

Effect of Urea When Used as a Substitute for Linseed Meal

Lot	Ration	Change in body wt.	Av. Test	Total milk Pdn.	Total B.F. Pdn.	Adjusted to 4% milk
1	Urea	+ 123 lbs.	3.02	11749.9	354.9	10029.0
2	Linseed meal	+ 117 lbs.	3.54	11843.7	419.8	11035.7

It will be noticed that while the two lots made similar gains in body weight and differed only 0.80% in total milk production the average butterfat percentage of milk from the urea-fed cows was definitely lower than that from the groups fed linseed meal. This not only affected the amount of butterfat produced but also resulted in a difference of 1,006.7 pounds of milk when corrected to 4% butter fat content.

However, since it was not possible at the beginning of the trial to match the cows evenly for fat test, this difference

in fat production could not be attributed to the difference in the rations fed.

Data obtained during this trial indicated that the urea ration was not completely palatable to dairy cows. While all cows fed the urea mixture consumed it more slowly than they had consumed the linseed meal mix, certain individual cows demonstrated more dislike than others. One cow on the urea ration gradually went off feed and was removed from the experiment after she had lost considerable weight.

Second Experiment: 1944-1945.

Data obtained in the first experiment were considered insufficient to provide a conclusive answer to the effect of substituting urea for linseed meal. Consequently, a similar experiment was outlined for the winter of 1944-45.

Fourteen cows in all were chosen for the experiment but since two of them went off feed early in the feeding period it was possible to make comparisons between only 12 cows. These cows were divided into lots, matched as evenly as possible for breed, age, stage of lactation, milk flow and body weight, and allocated to three different rations in such a way that direct comparisons were possible between each of the following grain mixtures:

1. Urea (2%)
2. Urea (1%) and linseed meal.
3. Linseed meal.

Table III gives the composition of these three grain mixtures.

Table III

Composition of the Grain Mixtures Fed

	Urea mixture	Urea-linseed meal mixture	Linseed meal mixture
Wheat bran	400 lbs.	400 lbs.	400 lbs.
Oats	1160 "	1030 "	900 "
Barley	400 "	400 "	400 "
Urea	40 "	20 "	-
Linseed meal	-	150 "	300 "
	2000 lbs.	2000 lbs.	2000 lbs.
Crude protein equivalent (N x 6.25)	18.1%	16.4%	14.8%

The roughage requirements of these cows were met by green oat silage and a mixed timothy-oat hay. As in the previous experiment the cows were fed according to the Morrison standards and using the weekly data for body weight and production.

Table IV summarizes the results obtained in this experiment.

In general it may be stated that the substitution of urea for all or part of the linseed meal in the grain mixtures fed to lactating cows had no discernible effect on their milk production, fat production or body weight. Differences in fat test between comparable groups were between 0.05% and 0.08%, which proves that, under the conditions of this trial, the feeding of urea had no effect on the butter fat test.

Table IV

Effect of Urea When Used as a Partial or Complete Substitute for Linseed Meal.

	No. Cows	Actual Milk Production lbs.	Av. Test	Actual Butterfat Production lbs.	Milk Production on 4% Basis lbs.	% Weekly Decline in 4% Milk Production
Urea ration	5	8,261.2	3.29%	272.0	7,384.3	1.65
Linseed Meal ration	5	8,369.1	3.21%	268.5	7,483.1	3.36
1/2 Urea - 1/2 Linseed Meal ration	7	12,205.4	3.56%	427.2	11,290.1	1.14
Linseed Meal ration	7	12,569.3	3.50%	447.2	11,852.6	2.29
Urea ration	4	7,541.0	3.00%	226.5	6,413.7	1.16
1/2 Urea - 1/2 Linseed Meal ration	4	7,333.3	3.05%	223.7	6,288.8	1.35

Once again, however, the problem of palatability appeared. Cows receiving a grain mixture containing urea always consumed it more slowly than they did a grain mixture containing bran and linseed meal as the protein supplements. Three cows, two Jerseys and one Holstein, refused to eat enough of the grain mixture to meet body requirements and had to be withdrawn from the experiment.

A thorough review of literature dealing with the feeding of urea to dairy cattle revealed no direct mention of unpalatability and further experiments were deemed essential to study this problem.

Third experiment: 1945-46.

In the fall of 1945 the Department of Animal Science undertook experimentation designed solely to investigate this palatability problem. The experiment was divided into two parts:

(1) The possibility of accustoming animals to the taste of urea by its gradual inclusion in their concentrate mixture.

(2) The effect of including certain feeds in the ration to disguise the taste of urea.

Part I: Three groups of cows were chosen for this part of the experiment. Cows of lot 1 were abruptly changed from a linseed meal mixture to a mixture containing 2% urea. The other two groups received gradually increased amounts of urea in such a way that cows of lot 2 received the full 2% urea mixture at

the end of three weeks and cows of lot 3 received it at the end of five weeks.

Table V indicates the rate at which urea was included in the rations of the 3 lots.

Table V

Rate at which urea was substituted for the linseed meal of the concentrate mixture in terms of the percentage of urea added to the ration.

	Lot 1	Lot 2	Lot 3
Preliminary weeks	no urea	no urea	no urea
1st experimental week	2.0%	0.33%	0.33%
2nd experimental week	2.0%	0.80%	0.66%
3rd experimental week	2.0%	1.60%	0.99%
4th experimental week	2.0%	2.00%	1.33%
5th experimental week	2.0%	2.00%	1.66%
6th and succeeding weeks	2.0%	2.00%	2.00%

The remainder of the cows in the herd were fed the usual linseed meal mixture and served, in a general way, to check the frequency of digestive and palatability disturbances.

The urea mixture and the linseed meal mixture were constituted as shown in Table VI. These mixtures were combined in proper proportions to obtain mixtures containing less than 2% urea.

Table VI

Composition of the Concentrate Mixtures Fed.

	Urea	Linseed meal
Barley	400	400
Oats	1160	900
Wheat bran	400	400
Linseed meal	-	300
Du Ponts "262" Urea	40	-
	2000	2000
Crude protein equivalent (N x 6.25)	19.1%	17.5%

The urea (Du Ponts "262" feed compound) was passed through a 1/16" screen before mixing to remove the small, hard lumps that were invariably present. To ensure thorough mixing all concentrate mixtures were mixed for one-half hour in a mechanical vertical-auger type mixer.

Roughage consisted of alfalfa, green oat hay and green oat silage. The cows were fed in accordance with the Morrison standards using weekly data of body weight and production.

Ten Holsteins and six Jerseys were fed for periods varying from 3 to 22 weeks in length. These cows were chosen so as to represent all stages of lactation and, when placed on the experiment, received grain allowances of 6# to 15# daily.

Results:

At no time did any cow on urea show the same relish for her grain allowance as did cows fed the standard linseed meal mixture, since they were slow to consume their allowance

and rarely licked up the last traces of grain in their manger. This had, however, no apparent adverse effect on body weight or milk production.

More aversion to urea was demonstrated by cows in Lots 2 and 3 that were gradually brought to a 2% urea mixture in three and six weeks respectively than by the cows in Lot 1 that were suddenly switched to the 2% urea mixture. The explanation for this is not apparent from the present data.

However, in addition to this rather passive aversion, there were five cows that developed an active dislike for the urea. These cows consumed their grain allowance more or less normally during the first part of the experiment and seemed to become accustomed to the urea. However, after about twelve weeks, they started to refuse part or all of the grain allowance and reduced milk yields and a decrease in live weight naturally resulted. It was found impossible to bring these cows back to full grain consumption on the urea ration but when they were offered the linseed meal mixture they consumed it with great eagerness.

The results proved that gradually increasing the urea allowance over a three- or a six-week period did not accustom the cows to the taste of urea as all cows gave evidence that they disliked the urea mixture.

The results also confirmed the results secured in the two previous trials and added further weight to the conclusion that urea feeding cannot be recommended until some successful method for its feeding is discovered.

In addition to these cases of unpalatability there was evidence that even low levels of urea in the ration might, in certain cases, have a harmful effect on the kidneys. One cow used in this experiment had developed a kidney disorder the previous year but had apparently recovered. On the urea ration she received 0.12 pounds of urea daily for 21 days during which time she lost weight and declined markedly in milk production. In the fourth week she suddenly refused all feed, showed an increased pulse and respiration rate and began to pass blood in her urine. The feeding of urea was immediately discontinued and in two weeks these symptoms of serious disorder had passed. However, she remained in an unthrifty condition for the balance of the winter and showed continuous diuresis.

Part 2: To determine whether certain feeds will disguise the taste of urea.

When cows developed a definite dislike for the urea mixture fed in the first part of this experiment their rations were altered to determine whether (a) a urea-corn grain mixture, (b) the addition of molasses, (c) a change in kind of hay fed, would disguise the taste of urea and render rations containing this compound more palatable.

The urea grain mixture containing corn was formulated as recommended by the manufacturer of the "262" feed compound while 10% of molasses (Betalasses) was added to the 2% urea grain mixture to compound the molasses mixture. The composi-

tions of the corn and molasses mixtures are shown in Table VII.

Table VII

Composition of the Grain Mixtures Containing Corn or Molasses

	Corn Mixture	Molasses Mixture
Barley	500	400
Corn	500	-
Oats	500	1160
Wheat middlings	200	-
Wheat bran	214	400
"262"urea	43	40
"Betalasses"	-	200
	1957	2200
Crude Protein Equivalent (N x 6.25)	19.4%	18.5%

Other cows were fed prairie hay in place of the alfalfa hay portion of their roughage allowance to determine whether a change of hay would alter their reaction towards the urea mixture.

Results:

(a) The urea-corn mixture was offered to only two cows. While both consumed it with somewhat more relish than they had the previous urea mixture, neither one would eat enough to meet body and production requirements. During the second week one cow refused to eat any of the urea-corn mixture during a 24-hour period. The other cow also failed to consume her daily allowance after three weeks of feeding the urea-corn mixture. While only two cows were used, they gave sufficient evidence that the addition of corn did not wholly disguise the taste of urea.

(b) Of the four cows used to study the effect of changing the roughage, three had demonstrated no more than a passive dislike for the urea mixture. Prairie hay was substituted for the alfalfa hay which had been fed. The three cows mentioned remained on prairie hay for 13 weeks, and during this time consumed their urea mixture with no greater lack of enthusiasm than that demonstrated by cows receiving alfalfa. The fourth cow that had already shown a definite dislike for the urea mixture when receiving alfalfa, continued to show the same dislike when prairie hay was fed. When, after three weeks, she was returned to alfalfa she continued to refuse her grain.

The feeding of the different hays apparently did not have any effect on the way the cows ate their urea mixture.

(c) Molasses was added to the urea mixture fed to two cows that showed a definite dislike for urea. The urea-molasses mixture proved exceptionally palatable, and for the first time in the experiment cows fed a urea mixture showed a keen appetite for their grain. They received this urea-molasses mixture for four weeks, during which time they consumed their full allowance without hesitation. The grain mixture was increased from 2% to 3% urea and fed to the same two cows. During the five weeks they were under observation on this increased urea allowance they failed to show even the slightest dislike for the urea-molasses mixture.

Summary:

1. Urea, when added to mixtures of feeds commonly used in dairy rations, causes the mixture to be unpalatable and as a result the animals may refuse to consume their required minimum daily allowance.

2. Gradual inclusion of urea in the grain mixture will not accustom the cows to the taste of this feed compound.

3. The inclusion of corn in the urea mixture made it somewhat more palatable, but this method of feeding urea does not seem applicable in western Canada when the availability and cost of corn are taken into consideration.

4. Type of roughage fed has little or no effect on the palatability of the urea mixture.

5. Molasses (Betalasses), when added to a 2% or 3% urea concentrate mixture, successfully disguised the flavor of urea.

Conclusions:

This experiment emphatically confirmed the unpalatable nature of urea and demonstrated, in a limited way, how urea may be successfully fed. However, several problems related to palatability of urea still remained unsolved.

One problem is to determine the minimum amount of molasses required to ensure palatability of grain mixtures containing various amounts of urea. A second problem is to investigate the basic cause for the unpalatable nature of urea and to establish whether continued feeding of urea may cause any physiological disturbance.

Further experiments were outlined to study these two problems and this phase of research was commenced in the fall of 1946 with financial assistance from the Consolidated Mining and Smelting Company of Canada, Limited.

Palatability Studies During 1946-1947

Originally this study was planned to investigate the amount of molasses required to ensure the palatability of a concentrate mixture containing the maximum amount of urea that might be fed. (The Association of American Feed Control Officials' Resolution No. 20 adopted in 1941 and amended in 1944 reads in part, "....Urea is to be used only in such limited quantities as to insure that the total amount present does not exceed 3% of the total grain ration".)

As this experiment progressed the results obtained, together with information gained from correspondence with various commercial feed companies and experimental stations, suggested that other experiments of importance in the study of palatability be undertaken in addition to that of the use of a molasses supplement.

Thus the results of the experiments with urea during the winter of 1946-47 are dealt with under the following sections:

(1) Use of molasses in urea rations.

(2) Palatability of rations containing small amounts of urea.

(3) Additional studies.

Section 1 - Use of molasses in urea rations

Plan of Experiment

Three lots of four cows each were chosen for this experiment. Both Jerseys and Holsteins were included in each lot to determine whether there was any breed difference in the response to molasses supplements.

Since the problem was one of palatability and not of production it was not necessary to select the cows on the basis of age, milk production or fat production. However, an attempt was made to choose cows near the beginning of lactation to ensure feeding periods of reasonable length.

A concentrate mixture containing 3% urea was prepared and molasses added to portions of it to formulate mixtures containing 0%, 3%, 5% and 10% molasses. Table VIII shows the composition of these mixtures as well as the allocation of the three lots of cows to these mixtures. The 10% molasses mixture was to be fed only to those cows that refused the other mixtures.

Table VIII

Composition of the Concentrate Mixtures

	Lot 1 0% molasses	Lot 2 3% molasses	Lot 3 5% molasses	 10% molasses
Barley	540	540	540	540
Oats	1200	1200	1200	1200
Bran	200	200	200	200
"262" Urea	60	60	60	60
Betalasses	-	60	100	200
	2000	2060	2100	2200
D.P.	17.13%	16.71%	16.44%	15.80%
T.D.N.	71.24%	70.89%	70.65%	70.11%
Crude Protein Equivalent (N x 6.25)	20.26%	19.90%	19.66%	19.12%

The concentrate mixtures were prepared in a mechanical vertical-auger type mixer. Du Ponts "262" feed compound was the urea source and it was passed through a 1/16" screen before mixing to remove the many small but hard lumps always present. To ensure thorough mixing the urea mixtures were run through the mixer for one-half hour. Betalasses, a by-product of the sugar refinery at Raymond, Alberta, was premixed with oats before placing in the mixer. This method ensured a uniform incorporation of the molasses throughout the entire mix.

The cows were supplied with as much hay and green oat silage as they would readily consume. The hay, of excellent quality, consisted of one-half alfalfa and one-half timothy. Silage was also of good quality. Salt, bonemeal and water were fed ad lib.

Quantitative nitrogen determinations, using the Kjeldahl method, were carried out on all feeds, and the percent of crude protein was calculated. From these figures, and using the

digestion coefficients reported in "Feeds and Feeding" (23) it was possible to calculate the percent digestible protein in each feed. All these data appear in Appendix A and were the basis for calculating the digestible protein of the rations fed. The itemized analyses for T.D.N. and D.P. of each concentrate mixture fed during this part of the experiment are given in Section I of Appendix B.

The cows selected for this feeding trial received grain allowances varying from 5 pounds to 11 pounds daily at the start of the experiment. They were fed in accordance with their requirements as recommended by Morrison (23).

The allocation of cows to these experimental rations, their daily grain allowances at the start of the experiment, and the general results obtained appear in Section I of Appendix C.

Results

Results obtained did not indicate that either 3% or 5% of molasses was effective in improving the palatability of a 3% urea mixture. However, within any one experimental lot, individuality and breed of the cow were the most important factors determining their response to the urea-molasses rations.

In lot 1 (no molasses) only one cow, No. 2, showed a strong dislike for the ration. After the first 5 weeks of the experiment her grain consumption was below her requirements so she was given the 10% molasses mixture. After 3 weeks on this ration her grain consumption was back to normal and she was transferred to the 3% molasses mixture. She gave no evidence

of dislike for this ration and was taken off the experiment at the completion of her lactation.

Two other cows, No. 1 and No. 3, showed some dislike for the 3% urea mixture but always consumed it readily when it was mixed with silage. Cow No. 4, receiving 10 pounds daily of this grain mixture, did not refuse the urea ration once during the 20 weeks she received this ration.

In lot 2, (3% molasses) cow No. 5 was on experiment for only 3 days when she refused her grain allowance completely. She was replaced by cow No. 7 who showed no dislike for the ration and was retired from the experiment 12 weeks later when she completed her lactation.

Cow No. 6 showed some dislike for the ration but up to the 15th week on the experiment she consumed her grain readily when it was mixed with silage. In that week, however, she suddenly went off feed and was then transferred to the experiment described in section (3) of this report.

The two Holsteins, No. 8 and No. 9 of this lot, did not at any time during the experiment refuse to eat their grain allowance.

In lot 3 (5% molasses) a response was obtained similar to that secured in lot 2. One cow, No. 10, refused to eat enough of the 5% and later of the 10% molasses mixtures to meet her requirements so she was taken off experiment. Cow No. 11, though she showed some dislike for the ration, would always consume the grain readily when it was mixed with silage.

the completion of her Doctorate.

Two other ones, Nos. 1 and 5, [illegible] in the [illegible] were mixed with silage. Cow No. 5, receiving [illegible] of this preliminary, did not perform the same well as those during the 70 weeks she received hula ration.

In Lot 2, (5% molasses) cow No. 9 was an exception [illegible] only 5 days when she refused her grain all seven consecutive. She was replaced by cow No. 7 who showed no dislike for the ration and was retired from this experiment 12 weeks later [illegible] her Doctorate.

Cow No. 6 showed some dislike for the ration as on the 11th week on this experiment she consumed [illegible] when it was mixed with silage. At that week, however, she suddenly went off feed and was then transferred to the treatment described in section (3) of this report.

The two Calves, No. 7 and No. 9 of Lot 1, [illegible] at any time during the experiment within the [illegible] allowance.

In Lot 3 (5% molasses) a decline was observed [illegible] to weed secured in Lot 2. The cow, No. 10, [illegible] enough of the 5% molasses [illegible] the reference [illegible] need for requirements in the ration [illegible]. [illegible] No. 11, though she showed [illegible] for [illegible] along a decline was [illegible] as in the [illegible].

However, she completely refused her grain in the 13th week and was then transferred to the experiment described in Section (3) of this report.

The two Holsteins of this lot, No. 12 and No. 13, did not refuse their grain at any time during the experiment.

One general observation made during the course of this experiment was that all cows in the 3 lots mentioned showed some distaste for the urea-containing grain mixtures and failed to show the same eagerness at grain feeding time as that evinced by cows on the standard linseed meal mixture. This reaction was evident throughout the experiment.

Summary and Conclusions

Molasses, when constituting 3% or 5% of the 3% urea mixture, did not definitely influence the palatability of the rations, and even the inclusion of 10% molasses did not ensure that a 3% urea mixture would be palatable to all cows.

The results are confused by the existence of a definite breed difference in response to the urea-molasses rations. Six of the seven Jerseys fed in the experiment demonstrated a more or less marked dislike for the urea mixtures while only one of the six Holsteins showed a similar response.

Another confusing factor is the extreme individuality of the cows within a breed. This seems to be the most important factor in determining the response that will be given a concentrate mixture containing urea.

Since several of these cows were on urea rations in the winter of 1945-46 results obtained show that previous feeding of urea had no apparent influence on their reaction towards urea in the present experiment.

One additional observation made during the course of this experiment was that many instances of grain refusal were overcome by mixing silage with the grain at feeding time. From this it seemed reasonable to assume that the silage partially disguised the taste of the urea.

The results of this experiment do not indicate what influence 3% or 5% of molasses might have on the palatability of grain mixtures containing less than 3% of urea and further study on this problem is warranted.

Section 2 - Palatability of Rations Containing Small Amounts of Urea

Since 1943 feeding experiments with urea at the University of Alberta consistently demonstrated that rations containing from 1% to 3% of urea were unpalatable to dairy cows. At the same time reports from American experiment stations stated that rations containing 3% of urea were completely palatable and, on the basis of these results, feed control officials recommended that up to 3% of urea could be included in commercial dairy concentrate mixtures.

As the results obtained at the University of Alberta

were consistently in opposition to the conclusion reached by American authorities it was felt that correspondence with the various experiment stations and with the feed companies that include urea in their commercial mixes might provide valuable information regarding palatability. Accordingly, two form letters were prepared. One, sent to experiment stations at Utah, Cornell, Illinois and Wisconsin and briefly reporting results of experiments at the University of Alberta, requested information that could help to explain the divergency of results obtained. The other letter, sent to commercial feed companies, enquired about their experiences with palatability, the feeds used in compounding their urea mixtures, and other factors that might have a bearing on the problem.

Replies from the Illinois and Cornell stations indicated similar palatability problems. At Illinois the most satisfactory method found for feeding urea was to dissolve it in corn syrup or molasses (21). Cornell workers (15) suggested that urea be fed at a level of 0.5% of the concentrate mixture to ensure palatability. Dr. L. E. Harris of Utah (6) also suggested that urea be included at less than 1% or 2% of the concentrate mixture. The reply from Dr. G. Bohstedt of Wisconsin (5) suggested that there might be a difference in the reaction of breeds, since their work was done entirely with Holsteins. He also mentioned that the urea mixtures were usually fed on top of the allowance of corn silage.

The replies received from the various feed companies may best be summarized as follows:

(1) Four companies reported that palatability of the ration was an important factor if the level of urea was too high. One company stated that they received reports of unpalatability with their feed when it contained 1% by weight of urea.

(2) Heavy-producing cows and cows accustomed to careful feeding and management were most likely to show dislike for the urea mixtures.

(3) The amount of urea used in their concentrate mixtures ranged between 0.25% and 1%. Those containing the lower levels of urea proved most satisfactory.

(4) It was the general opinion that molasses, included in the concentrate mixtures, accounted for some degree of palatability.

One general conclusion drawn from this correspondence was that the previous recommended levels for the feeding of urea were too high and that 0.5% of urea was probably the upper limit at which urea should be included in a concentrate mixture if palatability was to be guaranteed.

Accordingly, an experiment was outlined to investigate the palatability of grain mixtures containing 0.5% and 1% of urea.

Plan of Experiment

Every attempt was made to formulate the 0.5% and the 1% urea grain mixtures from the same feeds as those used in the

linseed meal mixture fed to the dairy cows in the herd not on experiment, in order to minimize the use of grains such as barley that might have some influence on palatability.

Table IX shows the composition of these two urea mixtures. The linseed meal mixture is included for comparison.

Table IX

Composition of the Concentrate Mixtures

	Lot 1 1% Urea	Lot 2 0.5% Urea	Linseed Meal
Barley	290 pounds	-	-
Oats	600 "	745 pounds	800 pounds
Bran	100 "	200 "	200 "
Linseed Meal	-	50 "	100 "
"262" Urea	10 "	5 "	-
	1000 "	1000 "	1100 "
D.P.	12.64%	13.14%	12.70%
T.D.N.	73.60%	71.34%	71.96%
Crude Protein Equivalent (N x 6.25)	15.36%	16.20%	15.74%

These concentrate mixtures were prepared in the same manner as those mixtures fed in the experiment described in Section 1. The itemized analysis for T.D.N. and D.P. of each mixture is given in Section II of Appendix B.

Nine cows, most of them in an early stage of lactation, were selected for this experiment. Lot 1, consisting of 5 Holsteins, was assigned to the 1.0% urea mixture, while Lot 2 with 2 Jerseys and 2 Holsteins was assigned to the 0.5% urea mixture. Their grain allowances at the start of the experiment varied from 8 pounds to 13 pounds daily and grain was fed in

accordance with their requirements as recommended by Morrison (23).

The roughages fed were the same as those fed in the experiment described in Section 1 and salt, bonemeal and water were fed ad lib.

A summary of the allocation of these cows to their experimental rations and the general results obtained appears in Section II of Appendix C.

Results

The results obtained demonstrated some difference in palatability of these two mixtures and emphasized the importance of individuality of the cow in determining response to rations containing urea.

Four Holsteins of lot 1 (1% urea), whose grain allowances ranged from 8 pounds to 12 pounds daily, did not at any time show dislike for the 1% urea ration. They consumed their grain readily and during their 12 weeks on experiment showed no periods of feed refusal. The fifth Holstein, No. 18, however, refused to eat the grain mixture the first day so she was transferred to lot 2 on the 0.5% urea ration.

All but one of the cows in lot 2 (0.5% urea) showed dislike for their grain allowance. This one cow, No. 18, that had refused to eat the 1% urea mixture, did not show any dislike for the 0.5% mixture which she received for an experimental period of 12 weeks. Cow No. 19, another Holstein, initially

showed dislike for the grain mixture by incomplete consumption of her daily grain allowance, but as the experiment progressed she apparently became accustomed to the ration and cleaned up her allowance more completely. In the 8th week on experiment she was offered the 1% urea mixture but, as she refused this mixture after the first feed, she was returned to the 0.5% urea mixture.

One of the two Jerseys of this lot refused the grain mixture completely after the first feed and was withdrawn from the experiment. The other Jersey, No. 21, receiving 9 pounds daily of the mixture, demonstrated distaste by slow consumption of her grain allowance. This response was evident throughout the 8 weeks she was on experiment.

While these results would seem to indicate that the 1% urea mixture was more palatable than the 0.5% urea mixture the more logical interpretation is that the response obtained in the two lots is just further evidence of the differences in breed and the individuality of the cows. This is demonstrated by the fact that the two Jerseys showed dislike for the 0.5% urea mixture while four Holsteins ate the 1.0% urea mixture with no indication of distaste. In support of this conclusion it is significant that though some cows that refused to eat the 1.0% urea mixture would eat the 0.5% urea mixture the reverse situation never occurred.

Summary and Conclusions

In this experiment, while even the 0.5% urea mixture was

not palatable to all cows it was quite apparent that such a mixture was more palatable than those mixtures containing a higher concentration of urea. From these data it may be concluded that the amount of urea in a concentrate mixture is an important factor in determining the palatability of that mixture. Additional data were obtained in support of the observation that there is a breed difference in response to urea rations.

However, further studies on the palatability of the 0.5% urea mixture are essential since additional data are required to establish:

(1) the proportion of cows that will refuse to eat grain mixtures containing this amount of urea, and the amount of urea that such cows will tolerate in their concentrate mixture.

(2) the amount of molasses required to ensure the palatability of a 0.5% urea mixture to such cows.

Section 3 - Additional Studies on the Palatability of Urea

(1) Cobalt Supplementation:

During the urea-feeding experiments of 1945-46 it was noted that 5 cows ate the urea-grain mixture for about 12 weeks before manifesting marked dislike for it. This reaction suggested that continued feeding of urea may have in some way upset either

the physiology of the cow or the physiology of rumen digestion. To investigate these suppositions urine samples were collected from these cows and analyzed for pH and total nitrogen content. The pH of all samples was found to be within the normal range but the total nitrogen content was above the normal level. This increase could, however, be readily interpreted as a result of the decline in milk production that accompanied the period off feed. It was thus impossible to give any definite explanation of this delayed reaction to urea feeding.

In the experiment of 1946-47 a similar response was obtained. Two cows, No. 6 and No. 11, after consuming their 3% urea rations for about 13 weeks, suddenly went off feed. Here again no explanation was apparent.

A review was subsequently made of literature pertaining to dietary factors known to be implicated in anorexia of ruminants. One of the factors studied was cobalt and certain authorities (18) suggested that its relation to anorexia of ruminants was a result of its influence on the organisms of the rumen.

To investigate what influence dietary cobalt might have on this refusal of urea-grain mixtures cobalt chloride was fed at the rate of about 0.05 grm. daily to the two cows previously mentioned (No. 6 and No. 11). At the end of one week they had returned to full feed and the cobalt supplementation was discontinued. From this time until the end of the experiment they remained on full feed and showed no further dislike for the ration.

After this favorable response to cobalt three other cows (Nos. 10, 19 and 20) that had shown dislike for urea rations were fed about 0.05 grm. of cobalt chloride daily for 8 days. Reactions to urea rations following this treatment were varied. Cow No. 10, on the linseed meal mixture, refused the 0.5% urea mixture entirely. Cow No. 19, on the 0.5% urea mixture showed more liking for this ration but refused to eat a mixture containing 1% urea. The third cow (No. 20) had previously refused the 0.5% urea mixture entirely. However, when offered the same mixture following the feeding of cobalt, she ate it for three days before beginning to show dislike.

These limited data appear to indicate that dislike for a urea-grain mixture may, in some cases, be alleviated by the addition of a small amount of cobalt to the ration.

Conclusions:

Owing to the limited number of cows available for this experiment definite conclusions are impossible but the results obtained suggest that further experimentation is warranted to establish what effect the continued feeding of these urea rations with or without cobalt may have on the bacterial flora of the rumen.

(2) Free Choice:

To determine the importance of flavor of urea as a factor influencing the palatability of a urea-grain mixture, ten cows - 5 Jerseys and 5 Holsteins - were offered a linseed meal mixture

and a 0.5% urea mixture simultaneously. It was expected that they would consume the more palatable mixture first.

In no case was the linseed meal mixture favored over the urea mixture, which would tend to indicate that there was no difference in the acceptability of the flavors of the two mixtures. However, interpretation of this response is made difficult by the previous observation that no cow would refuse a urea-grain mixture the first time it was fed, even if that mixture contained 3% of urea.

Conclusions:

Flavor of urea may be a factor influencing the palatability of a urea-grain mixture but, if so, this flavor would seem to be such that cows will eat small amounts of it at least once before learning to recognize and reject it.

However, this reaction might also be interpreted as additional evidence that urea in the ration upsets the physiology of digestion and that refusal of the urea mixture results from this disturbance.

GENERAL DISCUSSION

Evidence gathered through two years of experimentation with urea indicates that taste of urea is not, per se, the factor determining the palatability of a urea mixture. On the contrary, the response accorded such mixtures is the response to be expected toward a ration that, while pleasing to the taste, causes certain reactions during digestion that may subsequently cause the cow to avoid it instinctively.

One explanation of the unpalatable nature of certain urea rations may be that they have a deleterious effect on the bacterial flora of the rumen. Recent work has demonstrated the bacteriostatic effect of urea (36) and it is quite possible that urea in the ration may, by inhibiting the growth of certain bacteria in the rumen, alter the bacterial flora and in this way upset the physiology of rumen digestion.

While this is merely speculation, several authorities have suggested that the nature of the rumen flora is an important factor conditioning the cow's response to a urea ration. Dr. C. W. Turner, in a review of the role of urea in ruminant nutrition, stresses the importance of determining the optimum conditions for bacterial growth with urea as the source of nitrogen, and asks the questions, "Are the favorable effects from certain rations due to the presence of growth-promoting factors for the rumen organisms? Will some vitamin-like substances or precursors of the vitamins aid in bacterial growth? Are trace elements of any importance?"

Certainly the response obtained when cobalt was added to the urea ration would tend to uphold the theory that the unpalatability of certain urea rations stems from some alteration in the rumen flora and that this change was reversed by the addition of cobalt to the diet.

However, to investigate this theory further experimentation must be undertaken to demonstrate what qualitative and/or quantitative changes occur in the rumen flora when urea rations with or without cobalt supplementation are fed.

CONCLUSIONS

Results obtained in the experimental work described in this report support the following conclusions:

(1) Individuality of the cow is the most ostensible factor influencing the palatability of a urea ration.

(2) Breed of cow is of some importance; in this experiment Jerseys were more prone to show dislike for urea mixtures than were Holsteins.

(3) Molasses (Betalasses) does, to a certain degree, enhance the palatability of a urea mixture, but even 10% of molasses will not ensure the palatability to all cows of a 3% urea mixture. Further experiments are required to determine the effect on palatability of including small amounts of molasses in mixtures containing 0.5% and 1% of urea.

(4) The mixing of grain with silage at feeding time will, to a limited degree, overcome the unpalatability of a urea mixture.

(5) The amount of urea in a grain mixture is an important factor in determining the palatability of that mixture.

(6) The response obtained when the urea rations were supplemented with cobalt, together with the apparent non-importance of flavor of these urea mixtures may be interpreted as evidence of an alteration in the rumen flora (and hence physiology of digestion) induced by the use of urea in the diet.

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APPENDIX TABLES

Appendix A

T. D. N. and D. P. of concentrates and roughages fed

Feed	*Average analysis				University of Alberta Analysis			
	Description	T.D.N.%	N%	D.P.%	N%	% Protein	*Dig. co-efficient	D.P.%
Barley	Common - not including Pacific Coast States.	78.7	1.89	9.3	1.74	10.9	79	8.61
Oats	"	71.5	1.92	9.4	2.16	13.5	78	10.5
Bran	Chiefly hard spring wheat	70.9	2.45	13.2	2.58	16.1	83	13.36
Linseed meal	Old Process - 37% protein	77.8	6.16	33.6	5.28	33.0	87	28.71
Urea	DuPonts "262"	-	-	-	40.6	253.8	**94	238.52
"Betalasses"		58.8	1.23	2.5	-	-	52	-
Alfalfa	Excellent	53.7	2.64	12.4	2.92	18.2	75	13.65
Alfalfa	Medium	51.1	2.56	12.0	1.81	11.3	75	8.48
Alfalfa - Timothy		50.2	1.86	-	1.71	10.7	-	-
Oats - cut feed		46.3	1.33	4.5	1.62	10.1	54	5.45
Oat silage		15.4	.32	1.1	0.51	3.2	55	1.76

* Feeds and Feeding, 20th Edition, F. B. Morrison. Appendix Table I.
** Harris, L., Work, S.H. and Henke, L.A. 1943. (9).

Appendix B

Composition of the concentrate mixture

Section I

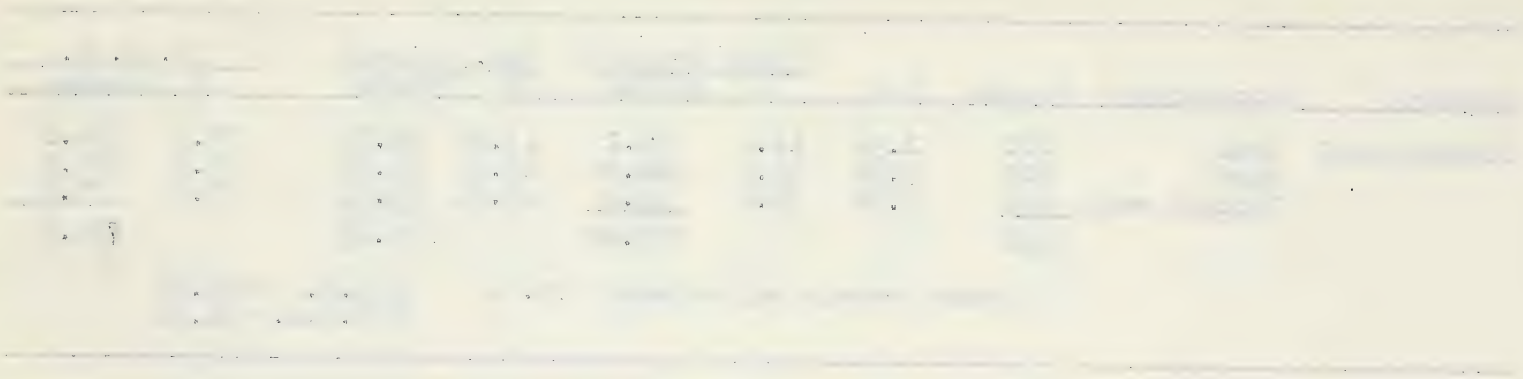
Mixture	Concentrates	Pounds	% N	Total Protein %	Total Protein Pounds	Dig. Protein %	Dig. Protein Pounds	T. D. N. %	T. D. N. Pounds
0% Molasses	Barley	270	1.74	10.9	29.43	8.16	23.25	78.7	212.5
	Oats	600	2.16	13.5	81.0	10.53	63.18	71.5	429.0
	Bran	100	2.58	16.1	16.1	13.36	13.36	70.9	70.9
	Urea	30	40.6	253.75	76.12	238.52	71.55	-	-
		1000			202.65		171.34		712.4
		Crude Protein equivalent = 20.26				% D.P. = 17.13			
						% T.D.N.= 71.24			
3% Molasses	Barley	270	1.74	10.9	29.43	8.16	23.25	78.7	212.5
	Oats	600	2.16	13.5	81.00	10.53	63.18	71.5	429.0
	Bran	100	2.58	16.1	16.10	13.36	13.36	70.9	70.9
	Urea	30	40.6	253.75	76.12	238.52	71.55	-	-
	Molasses	30	1.23	7.68	2.30	2.50	.75	58.8	17.6
		1030			204.95		172.09		730.0
		Crude Protein equivalent = 19.90				% D.P. = 16.71			
						% T.D.N. = 70.87			
5% Molasses	Barley	270	1.74	10.9	29.43	8.16	23.25	78.7	212.5
	Oats	600	2.16	13.5	81.00	10.53	63.18	71.5	429.0
	Bran	100	2.58	16.1	16.10	13.36	13.36	70.9	70.9
	Urea	30	40.6	253.75	76.12	238.52	71.55	-	-
	Molasses	50	1.23	7.68	3.84	2.50	1.25	58.8	29.4
		1050			206.49		172.59		741.8
		Crude Protein equivalent = 19.66				% D.P. = 16.44			
						% T.D.N. = 70.65			

Mixture	Concentrates	Pounds	% N	Total Protein %	Total Protein Pounds	Dig. Protein %	Dig. Protein Pounds	T. D. N. %	T. D. N. Pounds
10% Molasses	Barley	270	1.74	10.9	29.43	8.16	23.25	78.7	212.5
	Oats	600	2.16	13.5	81.00	10.53	63.18	71.5	429.0
	Bran	100	2.58	16.1	16.10	13.36	13.36	70.9	70.9
	Urea	30	40.6	253.75	76.10	238.52	71.55	-	-
	Molasses	100	1.23	7.68	7.68	2.50	2.50	58.8	58.8
		1100			210.31		173.84		771.2
				Crude Protein equivalent = 19.12			% D.P. = 15.80 % T.D.N. = 70.11		
Section II									
1% Urea	Barley	300	1.74	10.9	32.7	8.61	25.83	78.7	236.1
	Oats	600	2.16	13.5	81.0	10.53	63.18	71.5	429.0
	Bran	100	2.58	16.1	16.1	13.36	13.36	70.9	70.9
	Urea	10	40.6	253.75	25.38	238.52	23.85	-	-
		1010			155.18		126.22		736.0
				Crude Protein equivalent = 15.36			% D.P. = 12.50 % T.D.N. = 72.87		
0.5% Urea	Bran	200	2.58	16.1	32.20	13.36	26.72	70.9	141.8
	Oats	745	2.16	13.5	100.58	10.53	78.45	71.5	532.7
	Linseed meal	50	5.28	33.0	16.50	28.71	14.36	77.8	38.9
	Urea	5	40.6	253.75	12.69	238.52	11.93	-	-
		1000			161.97		131.46		713.4
				Crude Protein equivalent = 16.20			% D.P. = 13.15 % T.D.N. = 71.34		

Mixture	Concentrates	Pounds	% N	Total Protein %	Total Protein Pounds	Dig. Protein %	Dig. Protein Pounds	T. D. N. %	T. D. N. Pounds
Linseed meal	Bran	200	2.58	16.1	32.2	13.36	26.72	70.9	141.8
	Oats	800	2.16	13.5	108.00	10.53	84.24	71.5	572.0
	Linseed meal	100	5.28	33.0	33.0	28.71	28.71	77.8	77.8
		1100			173.20		139.67		791.6

Crude Protein equivalent = 15.74

% D.P. = 12.70
% T.D.N.= 71.96



Appendix C

Allotment of cows to the experimental rations

Cow	Experimental Number	Breed	Experimental Ration	Daily Grain Allowance at start of experiment	Weeks on experiment	Reaction to Urea
Section I						
Nan	1	Jersey	3% urea	10#	20 weeks	Some dislike for the 3% urea ration, ate it only when it was mixed with silage.
Pilgrim	2	Jersey	3% urea	5#	12 weeks	Strong dislike for 3% urea. On 10% molasses mix for 3 weeks then placed on the 3% molasses mix for which she showed no dislike. Off experiment at end of lactation.
Katie	3	Holstein	3% urea	11#	20 weeks	Very occasional dislike.
Rose	4	Holstein	3% urea	10#	19 weeks	No refusal.
Phila	5	Jersey	3% molasses	7#	3 days	Refused grain allowance completely after 3 days.
Polly	6	Jersey	3% molasses	8#	20 weeks	Some dislike from beginning but went off feed completely in the 15th week. Back to full feed after receiving cobalt for 1 week.

Cow	Experimental Number	Breed	Experimental Ration	Daily Grain Allowance at start of experiment	Weeks on experiment	Reaction to urea
Upsilon	7	Jersey	3% molasses	6#	12 weeks	No refusal of grain. Off experiment at end of lactation.
Flora	8	Holstein	3% molasses	10#	20 weeks	No refusal.
Rowena	9	Holstein	3% molasses	10#	20 weeks	No refusal.
Maxine	10	Jersey	5% molasses	10#	8 weeks	Immediate dislike for the ration. Could not be brought to full feed on the 10% molasses mixture so taken off experiment.
Theta	11	Jersey	5% molasses	10#	18 weeks	Showed occasional dislike during first few weeks but went off feed completely in the 13th week. Grain consumption back to normal after receiving cobalt for 1 week.
Clara	12	Holstein	5% molasses	8#	12 weeks	No refusal.
Louise	13	Holstein	5% molasses	9#	9 weeks	No refusal.

Cow	Experimental Number	Breed	Experimental Ration	Daily Grain Allowance at start of experiment	Weeks on experiment	Reaction to Urea
Section II						
Roma	14	Holstein	1.0% urea	12#	10 weeks	No refusal.
Rosina	15	Holstein	1.0% urea	8#	10 weeks	No refusal.
Roberta	16	Holstein	1.0% urea	11#	10 weeks	No refusal.
Rosy	17	Holstein	1.0% urea	8#	10 weeks	No refusal.
Edna	18	Holstein	1.0% urea	10#	1 day	Completely refused the mixture so transferred to the 0.5% mixture which she ate without refusal for 11 weeks.
Hilda	19	Holstein	0.5% urea	13#	11 weeks	Showed dislike for the ration throughout the experiment but always consumed her allowance. She was offered the 1% mixture in the 8th week, after receiving cobalt, but refused it completely.
Alpha	20	Jersey	0.5% urea	11#	1 day	Immediate refusal. After being fed cobalt for a week she would eat this mixture.
Winnie	21	Jersey	0.5% urea	9#	7 weeks	Occasional dislike.

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